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Application Note

WAVE SOLDERING AND LARGE MULTILAYER CERAMIC CAPACITORS

INTRODUCTION

Wave soldering was one of first production techniques for soldering surface mount components, including multilayer ceramic capacitors (MLCCs), to assemblies. initially, process problems such as inadequate preheat and excessive dwell time, and inferior ceramic capacitors [e.g. small voids and delaminations] caused cracking of the capacitors. Improved equipment and capacitors have reduced thermal shock cracking in smaller MLCCs, but even the most conservative time-temperature profiles seen In wave soldering, Fig. I below, still cause problems for the larger MLCCs, and particularly for High-Voltage MLCCs.

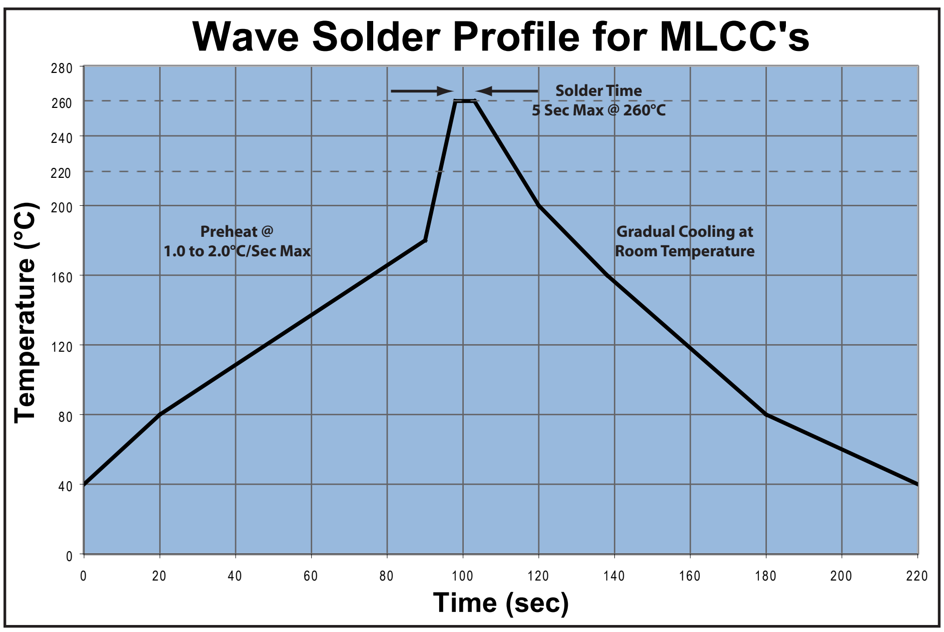

Fig. 1 Conservative Wave Soldering Time-Temperature Profile

THERMAL SHOCK SENSITIVITY OF MLCC'S

Multilayer Ceramic Capacitors (MLCC's) are complex composite mechanical structures composed of alternate layers of dense ceramic and metal electrodes. Alternate electrodes are connected on opposite ends with termination metals, which typically contain glass frits. As such, the MLCC is inherently sensitive to thermal and mechanical shock. The larger size of High Voltage MLCC's increases this sensitivity, in turn requiring greater care with conventional soldering techniques.

Thermal shock encountered with any soldering method can stress the device and lead to fractures ranging from invisible micro-cracks to visible cracks. The extent of cracking which may occur depends upon

• MLCC characteristics such as internal design [metal layers, arid number and thickness of ceramic layers] and nature of metal/ceramic Interfaces

• Structural considerations in addition to dimensions [e.g. MLCC corners heat up much more quickly than the interior, leading to rapid stress buildup, i.e. large temperature gradients between chip corners and the interior effect thermal expansion rates, due to differences in coefficient of thermal expansion and thermal conductivity of the materials used in the MLCC.]

• Extent of wetting of capacitor metal end terminations to the liquid solder, which increases heat flow and corner stress

• Parameters of the soldering process [e.g. time, temperature exposure and imposed temperature gradients, mechanical stress]

Accordingly, electrical failure8 can range from decreased insulation resistance to catastrophic failure [shorts], as well as poor partial discharge performance for High Voltage MLCC's.

In general, with High Voltage MLCC's, care must be taken, with preheat and controlled cooling, to prevent thermal shocking of the part. Large parts should not see more than 50°C difference between preheat and solder temperature versus 100°C for parts with footprints smaller than .250' x .200."

PRACTICAL CONSIDERATIONS

Preheat temperatures required to minimize capacitor cracking may introduce other problems with the assembly, laminate, flux and top side solder joints,

The glass transition temperature of the popular FR-4 laminate material that is used in printed wiring boards (PWB) is approximately 115°C. At higher temperatures, the laminate softens, and a large assembly may sag during the preheat cycle, allowing it to scoop solder onto the top of the PWB.

Organic solder flux materials typically have maximum preheat temperatures less than 125-150°C, limiting the use of these materials.

• Above these maximum temperatures, organic fluxes do not perform their function of metal oxide reduction, causing solderability problems.

• High preheat temperature exposure may 'bake-on" the flux materials, making water cleaning very difficult.

High preheat temperatures also tend to bum off no-clean fluxes, again causing solderability problems.

Topside solder joints from prior reflow soldering operations may become damaged by heat flow during the preheat cycle. Accelerated solder grain growth, which can reduce solder joint strength and Integrity, occurs at temperatures approaching the eutectic temperature, approximately 185°C for most common solders,

High preheat temperatures also limit the physical size of topside components to small integrated circuit packages and passive components, to minimize solder joint damage due to stresses related to size and varying coefficients of thermal expansion.

CONCLUSION

Large MLCCS can be wave soldered, but care must be taken to eliminate thermal shock by incorporating high preheat temperatures, slow preheat rates and controlled gradual cooling. Unfortunately, the high preheat temperatures usually preclude the use of wave soldering when faced with other assembly considerations such as solderability, flux compatibility, laminate size and sag, and topside solder joints.